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Are European Equity Style Indexes Mean Reverting?

Testing the Validity of the Efficient Market Hypothesis

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Abstract

The article tests for a random walk in European equity style indexes. After briefly introducing the efficient market hypothesis, equity styles in general and the used statistical techniques (*Variance Ratio Test* and modified *Rescaled Range Test*) it is shown that a random walk in European equity style indexes cannot be rejected. At least in the period since the mid 70s, for which this research has been conducted, the *weak* form efficient market hypothesis seems to hold.

Keywords: Efficient Market Hypothesis; Variance Ratio Test; Rescaled Range Test; Equity Style Investment.
JEL Classification: G14, G11

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I. Introduction

What if security prices were predictable? Wouldn't that imply that knowledgeable investors were able to make substantial above average profits on this basis? But the question of predictability is essentially just part of the greater question of efficiency and of the validity of the efficient market hypothesis (EMH). Although the EMH, in its current form, only exists since the late 60s, in some way or another it was always around; early references of this topic reach back as far as the late 19th century[1]. Still, most empirical studies were initiated by the work of Fama and French in the late 60s, which put the EMH into a formal framework. In the following years, no definitive confirmation or rejection of the hypothesis was found and research on this subject either only or mostly involved data from the United States. Further, in the area of equity style indices, only T. Daniel Coggin (1998) produced a time series analysis, again with data taken from the USA stock markets. This is especially interesting as equity styles try to use a certain pattern in securities to make extensive returns, which if it holds would be a violation of the EMH For example, as the reader will see later on, the contrarian approach assumes, that a falling share price makes a specific stock cheaper rather than riskier and an investor following this approach expects the share's price to eventually turn around and start rising again. Hence, a negative serial correlation in share prices could be observed, which would be a contradiction of the EMH. In other words, equity styles prove a good testing ground for the EMH, as for them to work, the EMH has to fail.[2]

It hence is the aim of this research project to analyze the possibility of correlation in equity style indices' returns for Europe, in order to provide a more thorough insight into the issue of security price predictability.

After a short introduction into the EMH and the general topic of style investment a thorough literature review will give the reader an overview of the empirical work as it has been conducted on the topic. With the help of the *Variance Ratio Test*, as well as the *R/S-Test*, which both will be introduced later, several European Style Investment indices will be examined for a random walk, the latter being a clear consequence of the EMH.

Before moving on to the centerpiece of this discussion, it seems appropriate to give the reader a quick introduction into the theoretical background of this topic.

1 See section I.1. for a quote on market efficiency by George Gibson from 1889.

2 Saying this, though, the reader should note, higher profits alone are not enough to falsify the EMH. The superior earnings gained by following an investment style have to be risk-adjusted for the EMH to fail.

I.1. The Efficient Market Hypothesis

The notion that financial markets are '*efficient*' is one of the most controversial topics in economics and many empirical studies, not to mention the ongoing theoretical debates, come to differing conclusions. But what exactly is the definition of efficiency? Originally introduced in 1965 by Fama, the Efficient Market Hypothesis (EMH) stipulates three different forms of efficiency:

1. *weak*: all necessary historical price and return information is incorporated in an asset's[3] current price. In other words, it is impossible to gain an advantage over other investors by analyzing past price or return data of a stock as this information has already been utilized; it is impossible to earn superior average risk-adjusted returns.[4] Under the assumption of risk neutrality this reduces to a random walk (Fama 1965); price increases at any given day are as likely as price decreases. The underlying random walk model looks as follows:

   $$p_t = \lambda + p_{t-1} + \varepsilon_t \qquad (1),$$

   $$\Leftrightarrow \qquad \Delta p_t = \lambda + \varepsilon_t \qquad (2),$$

   where

   p_t is the natural logarithm of the stock price at time t,

   λ is expected drift (an arbitrary parameter) and

   $\varepsilon_t \sim (0, \sigma^2)$ is the random disturbance term and its elements are uncorrelated but dependent.[5]

   In other words asset prices are essentially unpredictable on the basis of past price or return data.

2. *semi-strong*: all necessary publicly available information, not only past price and return data, is incorporated in the share price. Again, investors are not

3 In general the EMH applies to all kinds of financial market assets. In the following, though, stocks and shares are the main focus and will be used exemplary for all possible assets.

4 Returns in these circumstances always have to be seen on a risk-adjusted basis, as higher returns can be the result of more risk borne by the investor. In other words, the EMH does not suggest it is impossible to earn a greater return than any investor, but rather than any investor bearing the same amount of risk.

5 An example for such a process is: $Cov[\varepsilon_t;\varepsilon_{t-i}] = 0$ and $Cov[\varepsilon_t^2;\varepsilon_{t-i}^2] \neq 0$ for all $i \neq 0$. This represents a deviation from the usual random walk model, which assumes $\varepsilon_t \sim IID(0, \sigma^2)$, or to put it differently, where the increments of the error term are independently and identically distributed (*IID*). The IID assumption of the "normal" random walk model is highly restrictive and represents a special case of the model which is used here.

able to gain an advantage over their peers and price movements are purely the result of so far unknown information or unanticipated events. Thus, superior risk-adjusted average returns are implausible.

3. *strong*: all necessary, not only publicly available, information is incorporated in current stock prices. In other words, even so called insider information does not allow to earn excessive average risk adjusted returns. While the many insider trading cases that have been brought to courts and where up to that point profitable, clearly indicate a failure of the *strong* form EMH. Still the theoretical reasoning behind this definition goes as follows: Insider information cannot be held secret for long enough and will rather sooner than later spill into the financial markets via rumors. If this happens, the once "insider" information has become publicly available information and the *strong* form EMH reduces to the *semi-strong* form. If that was the case, again no abnormal profit would be plausible at all.

It should be noted, though, that the intuition behind these definitions far precedes the EMH; the collective judgment by many knowledgeable investors produces the most efficient price and incorporates all necessary information. Or as it is put in a book by George Gibson from 1889:

> *"[…] shares become publicly known in an open market, the value which they acquire may be regarded as the judgment of the best intelligence concerning them."*[6]

The reasoning goes further: If this was not the case, these knowledgeable traders would use their information advantage to earn excessive returns by buying cheap and selling dear. Indeed they would participate in an act of arbitrage. Eventually, competition between these traders would grow, as more and more participants try to earn returns on the above basis until profit margins adjust downwards and prices start to move randomly again; thus price movements reduce to a random walk.[7]

By the late 70s and early 80s the EMH, due to its intuitive structure, but also based on early empirical work seemed to be one of the few "real" success stories in economics. Michael Jensen, one of the creators of the EMH from Chicago, even was lead to saying that "*there is no other proposition in economics which has more solid empirical*

[6] George Gibson (1889), p. 11

[7] This intuitive arbitrage argument for the EMH is not without its opponents, though. If one was to introduce constraints (e.g. time and/or liquidity constraints) on these arbitrageurs, it is doubtful whether they would be able to remove the inefficiencies in the manner described above. The interested reader should refer to Shleifer (2000) for a more detailed discussion of this argument.

evidence supporting it than the Efficient markets hypothesis" (Jensen 1978, p. 95). But as usual in economics, as soon as such a strong declaration has been made, the tide tends to turn.

As implied by the EMH, price changes should follow a random walk and hence should be uncorrelated with past price or return data. Testing for a random walk, hence, seems like a plausible way to test the EMH. Firstly, the properties of a random walk are well known, which simplifies the test procedures. Secondly, if no random walk can be identified it would violate the *weak* form EMH. But as the *semi-strong* as well as the *strong* form EMH are based on the *weak* form, they too would be falsified. Over the years as statistical techniques developed further several anomalies and evidence against a random walk was found that suggested both positive as well as negative serial correlation. For example DeBondt and Thaler (1985) identified long-term trends, which in time tend to reverse themselves (negative serial correlation) just as Jagadeesh and Titman (1993) identified positive serial correlation, as price movements over a period of 6 to 12 months seemed to indicate future price changes in the same direction. These findings opened the way for an alternative view of the financial markets: behavioral finance. It tries to explain the various inefficiencies in financial markets through human psychology rather than pure rationality. Or as John Maynard Kaynes put it long before this field of research had developed:

> *"[…] day-to-day fluctuations in the profits of existing investments, which are obviously of an ephemeral and non-significant character, tend to have an altogether excessive, and even an absurd, influence on the market." (Keynes, 1936, pp.153-154).*

Through the evidence against a random walk in share prices as found for example by DeBondt and Thaler (1985) and Jadadeesh and Titman (1993) and behavioral finance an alternative model developed: mean reversion. It suggests, while short-term positive trends tend to push prices away from an efficient value, that reflects the intrinsic worth of a share, in the longer-term the price will revert to its "mean" and hence to its innate appropriate value. Or to put it differently, after several years of bull mentality in financial markets, prices would have to drop again, in order to return to their historic mean. Summers (1986) offers a slowly decaying stationary price component[8] as a theoretical foundation, which could form in two different ways:

1. financial markets taking long swings away form their innate value due to irrational trading, so called noise trading

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[8] See Summers (1986) and the following literature review for a further discussion of the slowly decaying stationary price component.

2. ‘time-varying equilibrium expected returns’ within an efficient and rational market

Finally, mean reversion especially in the long-run, seems like the only plausible alternative to a random walk. Surely one can easily imagine a period of positively correlated stock returns, but over time such a situation would lead to explosive asset prices, which eventually have to come back to their innate value; revert to their mean:

I.2. Equity styles

Since the 70’s, when the notion of equity styles first appeared, the concept has grown to become a major investment tool in toady’s financial markets. Not only do large institutional investors and their clients use equity styles, but also more and more private and small investors are adopting these investment techniques. It’s due to this, but also to the fact, that equity styles try to exploit a certain systematic pattern in share prices (the reader should refer to the contrarian approach, as quickly introduced in the introduction or further on in the text for a good example), which makes them the ideal “yardstick” for EMH testing. Should equity styles work, they would produce superior average risk-adjusted returns, which is a violation of the semi-strong and the strong form EMH. Or, to put it differently, effective equity styles and the EMH, expect for the *weak* EMH, are mutually exclusive.

But what exactly is meant by equity style?

An equity style is a certain investment philosophy shared by a group of investors and constitutes specific factors that are supposed to drive a stock price. Further, the style should be introduced to the market purely on the basis of philosophical belief on the side of investors, rather than theoretical research (Coggin, Fabozzi and Arnott, 1997).

The easiest way to separate the most common existing styles, is by share size:

1. large capitalization (*LargeCap*): large and highly traded companies, measured by their market capitalization (outstanding shares multiplied by price). This represents the most common style. Large Cap shares offer investors a high flow of information, which simplifies their analysis. Due to their size, they are covered more frequently by the financial media as well as financial analysts. Also they are usually subject to tougher reporting regulations than their smaller peers. Further, greater coverage and flow of information about a share decreases the risk of a single investor to overlook a specific problem; many other analysts will have already investigated the case and would have reported any problems. It is this reason why *LargeCap* is especially interesting to inexperienced investors: size implies security.

2. *small capitalization (SmallCap)*: small and relatively poorly traded shares as measured by their market capitalization. This style has certain advantages

over its *LargeCap* counterpart, as smaller firms are not so widely researched and analyzed by big institutional investors and hence offer greater profit prospects. Contrary to the EMH, this style is based on the believe that *SmallCap* shares are neglected by most investors. Hence information about these stocks is not being handled efficiently, which opens the possibility for excess risk-adjusted returns. A portfolio guided by *SmallCap* investment will tend to include below average dividends, high risk in comparison to the overall market, high betas and few institutionally analyzed shares.

3. middle capitalization (*MidCap*): shares with a market capitalization between *LargeCap* and *SmallCap*.[9] According to 'The Handbook of Equity Style Management' by Coggin, Fabozzi and Arnott (1997) one can point out, though, that it is debatable whether *MidCap* investment is indeed an equity style as defined earlier. It was not introduced by market adaptation, but rather through theory and only then found its way into day-to-day market use. Nonetheless, since *MidCap* investment is constantly growing in popularity and one can easily find evidence for a *MidCap* segment in financial markets, it is the authors believe, that it should be included in this discussion of equity styles, in order not to give the reader an incomplete overview of the existing styles. *MidCap* managers seek to gain added value from the fact that they are investing in a separate market segment, and hence try to exploit the differing behavior of this segment in contrast to their *Small and LargeCap* counterparts. Since this 'style', though, is relatively new, not much data can be found on it yet. In other words, only time will tell how *MidCap* investing will evolve and whether it will ever become an equal counterpart to *Small and LargeCap*.[10]

From here one can now make many further distinctions within the above 3 major groupings. The most common of these sub-styles will be introduced in the following short sections.[11]

I.2.a. Value

In general it can be said that *Value* investors see the price of a share as the important parameter. They look at issues such as low p/e ratio or high yield. In

[9] It should be noted that *MidCap* is not just the residual of *LargeCap* and *SmallCap*, but individually chosen shares.

[10] The lack of data is also the reason why *MidCap* will not be analyzed here.

[11] If the reader should be interested in more detailed information concerning this topic he/she should refer to 'The Handbook of Equity Style Management' by Coggin, Fabozzi and Arnott (1997) for a more complete discussion.

other words they try to invest in stocks, which they deem to be '*cheap'* in comparison to other alternatives, because of temporary market mentality or cyclical disturbances. A *Value* investor hence relies on future price increases, rather than fundamental changes within the company. They usually are one of the first to participate in a specific share's price rise, but also one of the earliest to sell the share again as the price will get too high for their liking.

From the above introduction to mean reversion it can now be seen how *Value* investing is the most obvious result from the idea that share prices will temporarily deviating from their fundamental value, but eventually will return there. In fact, as the reader will see further on, one can identify a specific form of *Value* investment that has to be seen as a direct implementation of the mean reversion notion: the contrarian approach.

As a specific philosophy will not be used in the same manner by every investor within one equity style, one can identify three major types of *Value* styles.

I.2.a.i. p/e ratio

Under this approach a low p/e ratio is the deciding factor for an investment in a particular share. Managers that follow this form look for relatively low prices in comparison to normalized, future or current earnings, which usually is the case for cyclical, unfavoured and defensive operating firms. Or, in other words, they look for shares with relatively healthy earnings per share but, due to whatever reason, low prices, which then results in a low p/e ratio as well. The real skill involved in this technique is finding a low p/e company that has a healthy earnings situation, but is not '*appreciated'* by the market.

I.2.a.ii. yield

Yield managers look at companies with above average dividend yield and hence he/she behaves very similar to a p/e ratio investor, as only their measure of earnings differs. Managers of this type are among the most conservative ones in the *Value* section, as they make their decision upon the most conservative and probably most constant factor in financial markets: dividends.

*I.2.a.iii. Market-to-book-value (*mtbv*)/contrarian approach*

Contrarian or Market-to-book-value (*mtbv*) managers invest in shares that are currently cheap in relation to their tangible book value. Investors hope for one of three things, a cyclical turn-around, company specific future earnings growth, or simply a rebound, which will rectify the market's "wrong" perception. A simple example of this can be seen quite frequently in financial analysts buy recommendations: A drop in a specific share price is often not seen as a warning, but rather as a buying opportunity. Prices are expected to rebound in the future and hence the lower current price, as compared to the prior higher price before the decline, allows for a greater profit. In fact an investor following this approach tends to do exactly the opposite of the general market, hence contrarian approach. He/she hopes that in time the price will rebound and in that case they have been able to "beat" the market and so earned an excessive return. This clearly represents the style that tries to exploit a possible mean reversion most directly.

I.2.b. Growth

In contrast to his/her counterpart in *Value* investing, the *Growth* manager is not interested in the current price of a company's share, but its future earnings with a constant p/e ratio. It follows that if the p/e ratio is to stay constant and the earnings are to rise, the price of the share has to rise as well, hence the initial price of the share is irrelevant to the *Growth* investor. In other words, the *Growth* approach denotes the opposite technique of the earlier described *Value*-p/e (price to earnings) ratio style. Prime examples are the high tech shares of the late 90s. Two forms of *Growth* investment can be identified:

I.2.b.i. earnings momentum

A manager adopting the earnings momentum approach looks for companies with above average earnings growth, which fairly often can be volatile as well. These firms will come from any industry, as long as the future earnings growth promises to be high enough.

I.2.b.ii. consistent earnings growth

As its title implies an investor following this approach does not so much value above average earnings growth, but rather consistent growth of earnings; it denotes a more conservative version of *Growth* style. Consistent earnings growth portfolios, usually include market leaders in stable industries. Very few cyclicals are being purchased, due to their volatility in growth. Additionally, it is common, that prices well above market multiples are being paid for consistent earnings growth stocks, as it is assumed that the development in earnings will outperform the negative downside of such high buying prices.

I.2.c. Market-oriented

This styles, as its name indicates, incorporates managers with no special characteristic preference and hence their portfolios tend to be matching the broader market during business cycles more closely. It follows that a large variety of managers fall into this segment, each with their own specific strategy. Still, even in this style certain forms have developed over the years that, in general, represent the existing other equity styles:

I.2.c.i. Value *biased or* Growth *biased*

This form of market-oriented manager has a tendency towards the *Value* or *Growth* style, but his/her preference is not strong enough to include them in the pure strategy above, as they also tend to include other styles in their investment approach.

I.2.c.ii. growth at a price

Managers of this form invest in companies with above average growth prospects at below market value. In other words they try to form a mixture of *Value* and *Growth* strategy and hence can be seen in a more central position within the equity styles. With respect to shares and market capitalization they tend to have a less diversified portfolio than other market-oriented managers.

I.2.c.iii. market normal

Market normal managers represent probably the most conservative type of portfolio managers, as they try to arrange their portfolio to resemble the broad market without a certain bias towards any particular equity style. They are the logical result of the EMH. For them the market truly knows best and so they don’t even try to beat their benchmarks, but rather structure their portfolio in an at least similar way. Still, investors with switching equity styles and no persistent tendency towards a particular strategy, are often included in this sub-section, as well.

II. Literature review

Before going into the literature review, it should be noted that over the years several ways to test the EMH have emerged. Probably the most common is to test for a random walk in the price/return data by means of statistical tests. Should a random walk be falsified, the *weak* form EMH would be violated and with it the whole EMH, as the two stronger forms are based upon the *weak* form. But there are at least two other major approaches, which have developed over the years. The first, as pioneered by Shiller in the early 80s of the last century, is to seek for excess volatility in stock prices by comparing the discounted future dividends with current stock prices. The EMH implies that current share prices are the best predictor of all future discounted dividends. Further, optimal forecasting demands, that a prediction should be less volatile than the variable forecasted. If this was not the case, the prediction would be systematically too low for low forecasts and systematically too high for high forecasts. In other words, it would include systematic errors (Shiller 2003). The EMH would proof invalid if one is able to find that current share prices are more volatile than all future discounted dividends (Shiller 1981). The second approach, as the EMH is always defined through the lack of superior average risk adjusted returns, is to test whether specific investors have constantly been able to earn a greater profit than their peers. For example one could test whether fund managers investing in American Blue Chip Shares have consistently been able to beat the performance of the S&P 500 Share Index. If this is the case, the EMH is in doubt (Malkiel 2003). Further, though, it should be noted, that in this case transaction costs gain a central role. As a fund charges transaction costs for investors to participate, a fund manager that performs exactly as well as his/her benchmark, will produce less profit for the investors than the alternative market-matching portfolio would have done.

This paper uses the first of these approaches and tries to test for a random walk. The following literature review will hence concentrate on prior works, which move along the same lines as well.[12] The question whether equity returns follow a random walk, hence not be predictable on the basis of past data, reaches back to the classic articles of Kendall (1953) and Fama (1965). These pioneering works on the basis of estimating correlation coefficients between stock returns came to the conclusion that no serial correlation and hence no mean reversion existed. They further followed that according to this, financial markets had to be *efficient* in at least the *weak* form.

As more sophisticated techniques evolved and the possibility to take a further, more long-term view of predictability in stock returns appeared, the 'Random walk'

[12] If the reader should be interested in the briefly introduced alternative ways to test the EMH, he/she should refer to either Shiller (2003) for a discussion of the excess volatility debate, or to Malkiel (2003) for a brief overview of the latter approach.

Hypothesis became challenged and such influential papers as DeBondt and Thaler (1985), Poterba and Summers (1988) and Fama and French (1988) seemed to show negative serial correlation in long-term equity return horizons.

Preceding Poterba and Summers' groundbreaking work from 1988, Summers (1986) introduced the notion of a slowly decaying stationary price component in stock prices. He argued that, contrary to the EMH, equity prices take long swings away from their fundamental values. On this basis, he arrived at a model for stock prices, which consists of a Random walk, x_t, plus a stationary price component, u_t:

$$p_t = x_t + u_t \qquad (3),$$

$$x_t = x_{t-1} + \lambda + \varepsilon_t \qquad (4),$$

$$u_t = \varphi u_{t-1} + \eta_t \qquad (5),$$

where

p_t is the natural logarithm of the stock price at time t,

λ is expected drift,

η_t is white noise,

φ close to but less than zero and

ε_t represents white noise as well.

Equation (4) is the same as the prior stated random walk model in equation (1).

The model was characterized by the fact that the stationary component accounts for the greatest share in price variations. This view later was supported by Fama and French's findings in 1988.[13]

Poterba and Summers (1988) started off their discussion by finding the best fit statistical technique and came to the conclusion that a *Variance Ratio Test* (*VR-Test*) seems the most appropriate. Nonetheless, they stated that even a *VR analysis* has relatively low statistical power and together with their assumption that *"[...]there is little theoretical basis for strong attachment to the null hypothesis that prices follow a Random Walk[...]" (Poterba and Summers; 1988, p.36),* they formed the believe that a standard confidence interval of 5% is too tightly chosen for this topic and suggested a widening. Further, they dismissed the usage of more sophisticated econometric techniques, as they believed that such methods, due to their highly complex and specified assumptions, would loose statistical power.

[13] The reader should refer to a later part of the literature review for a short introduction of this model.

They continued by using monthly real and excess returns for the NYSE (New York Stock Exchange) since 1926, the S&P-Cowles Commission stock price indices since 1871 as well as stock price data for 17 other equity markets net of dividend yields, to estimate the according variance ratios. This analysis yielded them with the result of positive serial correlation in the short horizon[14] and negative serial correlation in the long-term investment horizon, which in fact represents a case of mean reversion. These findings derived from a rejection of the 'Random walk' *Hypothesis* at a 15% level of confidence. It should be noted though, that Poterba and Summers (1988) did not find this pattern in every data set. Rather they drew the inference that a generalization can be made, as the above form of correlation was observed in most data sets. They further suggested that for the US 15-25% of the variations in stock prices are due to the stationary price component.

As a final analysis Poterba and Summers (1988) looked into the question of whether the observed mean reversion is due to noise trading or fundamental reasons, such as interest rate changes or market volatility. They concluded this part by suggesting noise trading to be the important factor for serial correlation.

Fama and French (1988) also based their research on the preceding earlier work of Summers (1986) and its stationary component.

They formed two different types of stock portfolio with equally weighted shares from the NYSE[15]: industry and decile portfolios, whereas the latter are dependent on share market capitalization. Furthermore, monthly portfolio returns were calculated and continuously compounded as well as adjusted by the CPI (US consumer price index) to express them in real terms. On this basis Fama and French (1988) estimated regression slopes with the help of an adjusted OLS model[16] for 1, 2, 3, 4, 5, 6, 8 and 10-year returns for the two kinds of portfolios. They found first-order autocorrelation that took a U-shape as return horizons increased. Whereas being only slightly negative for the short-term investment spectrum the autocorrelations reached a minimum for 3-5 year returns and then moved back towards zero negative autocorrelation. They concluded that these findings are consistent with a slowly decaying stationary component and depict the influence of the stationary components on stock prices, in their extreme values within a 3-5 year investment horizon, to be 60-90%.

[14] Positive serial correlation in short-term price changes were also found by Jegadeesh and Titman 1993 and is often justified by momentum or herd behavior in financial markets.

[15] New York Stock Exchange

[16] The method of bias adjustment is not explained here. In fact, the bias adjustment in Fama and French (1988) does not influence their results.

The fact that the negative correlation is *weak* in the short-horizon returns was seen as the reason why earlier studies rejected the possibility of mean reversion and negative serial correlation in stock returns, as they focused on short-term views.

Still, Fama and French's further studies of sub-periods show that, although the mentioned U-form in the negative serial correlation continued to exist in the post war period, it did so in a much weaker form and the greatest autocorrelation was observed in the pre-1940s. This leads Kim *et al.* (1991) to suggest that the found evidence is mainly due to a pre-WWII phenomenon, which is not applicable to stock returns today.

Finally, Fama and French (1988) pointed out, that due to high standard errors in their estimates the drawn conclusions can only be of indicative character and further studies into this field have to be undertaken in order to make precise inferences.

The findings by Poterba and Summers (1988) as well as Fama and French (1988) had a deep impact on the EMH, as even the *weak* form EMH seemed to be violated. As a result many researches either tried to modify the Random walk Hypothesis and the EMH by noise trading (Black, 1986), time-varying expected returns and risk perception (Lo and MacKinlay, 1988), fads (Lehmann, 1990) and market overshooting (DeBondt and Thaler, 1985) or simply questioned the validity of the above findings. The latter approach was taken by Lo (1991), for example. Using a *modified* R/S (*rescaled range*) *Test*[17], which eliminates short-range dependence, he finds no evidence of *Long-Term Memory* in stock prices. The above results may indeed be due to short-term memory rather than long-term dependence. Another example is Richardson and Stock (1989), who suggest that Poterba and Summers as well as Fama and French come to their above conclusions on the basis of an inapt asymptotic distribution. They put forward a distribution that allows the confidence interval for the *VR-Test* to remain at the 5% level and accept the random walk hypothesis.

A further set of articles by Richardson and Smith (1991), McQueen (1992), Chow and Denning (1993) and Richardson (1993) followed and employed joint tests of the *modified R/S-Test* as well as a *VR analysis*[18]. None of the mentioned discussions were able to reject the random walk hypothesis.

In 1996 two papers appeared that also used the above joined test of R/S and *Variance Ratio analysis* in their modified versions. They took a more international approach on the question of long-term dependence in stock returns. Chow, Pan and Sakano (1996) as well as Jacobsen (1996) were unable to reject a random walk, although it has to be said

[17] Lo modified the existing *R/S-Test*, which was first introduced by Hurst (1951) for long-range dependence. This method will be explained in more detail in the methodology section further on in the text.

[18] For further explanation of the statistical methods used in these articles see the methodology section.

that both find evidence in some countries of dependency. This dependency, though, was attributed – by using a rescaled *R/S-Test* – to short-term dependence, rather than long-term-memory.

Whereas the question of *Long-Term Memory* in equity returns is a much discussed issue, Coggin (1998) took this topic a step further and analysed it on the basis of equity style indexes; as style investment continues to grow in importance in portfolio management. He based his research on data from the S&P/BARRA as well as the CRSP (Center for Research in Security Prices) databases, which are available since January 1975 and July 1963, respectively. NYSE (New York Stock Exchange), AMEX (American Stock Exchange) and OTC[19] data is represented in these indexes and include such well-known broad market indexes as the S&P 500 as well as a range of equity styles indexes. Further he also used self-constructed and specialized arbitrage indexes.

Besides some basic statistical analysis and a correlation matrix, Coggin (1998) uses the same combination of methods as described above: the *Variance Ratio Test* as suggested by Lo and MacKinklay (1988) as well as the by Lo (1991) *modified R/S-Test*.

He adopted truncation lags from two to 120 months, which allowed him to simulate investment horizons of up to ten years.

Coggin (1998) was unableto reject a random walk on the basis of the *VR-Test* for either the broad market index or the several equity style indices. Further the *modified R/S-Test* delivered no evidence for *Long-Term Memory*.

He hence concluded that equity style indexes do not behave differently from broad market indices, they follow a random walk and hence cannot be predicted using past returns.

[19] OTC stands for ‘Over the Counter’ and represents non-standardized securities.

III. Methodology

The following sections will give the reader a quick overview of the techniques and the data used in this paper, as to point out some notable facts and to give the reader a more fundamental understanding of the procedures used.

III.1. Statistical techniques

Just like Coggin (1998) and several papers before him trying to verify a random walk in stock market data, this analysis employs the two standard tests:

1. *Variance Ratio Test* (*VR-Test*)
2. *Modified Rescaled Range Test* (*modified R/S-Test*)

In addition, the *classic R/S-Test* (the unmodified version by Hurst (1951)) will also be used. They all are fairly common techniques in the field of random walk testing and hence will only be described in a brief manner in the following section. Nonetheless, if the reader should need a more detailed explanation and/or would like information on their statistical properties as well as their robustness, he/she should refer to Lo and MacKinlay (1988) as well as Lo (1991), or in a more general case Campbell, Lo and MacKinlay (1997).

III.1.a. Variance Ratio Test

The *Variance Ratio Test* exploits the fact that under the assumption of a random walk a security's return variance should be according to its investment horizon. In other words, the variance of quarterly returns should be 4 times as great as the variance of the monthly return.

Obviously, this situation can easily be exploited in the following manner:

$$\frac{(\text{variance quarterly return})}{4(\text{variance monthly return})} = 1 \qquad (4),$$

or to put it in a more general form:

$$\frac{\sigma[r_t(q)]}{q \cdot \sigma[r_t]} \qquad (5),$$

whereas

$q =$ lag length (investment horizon)

$\sigma =$ variance

$r_t(q) = p_t - p_{t-q}$ (r_t is the special case with $q = 1$)

Together with a null hypothesis (H_0) of a random walk the application of the *VR-Test* is straightforward. If the ratios are '1', H_0 is accepted and will be rejected in any other case.[20] In specific the test follows the methodology introduced by Lo and MacKinlay (1988). It is heteroskedasticity robust and rectifies the problems as pointed out by Poterba and Sommers (1988). Also this approach does not rely on the highly restrictive IID (independent and identically distributed increments of the error term in the random walk model in equation 1) assumption, but relaxes it to dependent but uncorrelated increments for which IID is a special case. With n observations of log prices $\{p_1, p_2, ..., p_n\}$ and as n approaches infinity the variance ratios ($\overline{VR}(q)$) are calculated as follows:

$$\overline{VR}(q) = \frac{\sigma_b^2(q)}{\sigma_a^2} \quad (6),$$

where

$$\overline{\sigma}_a^2 = \frac{1}{n-2}\sum_{k=1}^{n}\left(p_k - p_{k-1} - \hat{\mu}\right)^2 \quad (7),$$

$$\overline{\sigma}_b^2 = \frac{1}{m}\sum_{k=q}^{n}\left(p_k - p_{k-q} - q\hat{\mu}\right)^2 \quad (8),$$

with

$$m \equiv q[(n-1) - q + 1]\left(1 - \frac{q}{n-1}\right) \quad (9).$$

The first variance estimator $\overline{\sigma}_a^2$ is the standard maximum-likelihood estimator corrected for its bias as suggested by Lo and MacKinlay (1988). The second variance estimator $\overline{\sigma}_b^2$ is a bias adjusted maximum likelihood estimator of greater return horizons (q). Clearly, $\hat{\mu}$ is the standard maximum-likelihood estimator of the mean (μ).

$\overline{VR}(q)$ is asymptotically normal distributed and the heteroskedasticity robust test statistic is

$$\psi(q) = \frac{\sqrt{n-1}(\overline{VR}(q) - 1)}{\sqrt{\hat{\theta}}} \overset{a}{\sim} N(0,1) \quad (10),$$

with

$$\hat{\theta}(q) \equiv 4\sum_{k=1}^{q-1}\left(1 - \frac{k}{q}\right)^2 \hat{\delta}_k \quad (11),$$

[20] Ratios below 1 indicate negative serial correlation, where as ratios greater 1 imply positive serial correlation.

and

$$\hat{\delta}_k = \frac{(n-1)\sum_{j=k+1}^{n-1}\left(p_j - p_{j-1} - \hat{\mu}\right)^2\left(p_{j-k} - p_{j-k-1} - \hat{\mu}\right)^2}{\left[\sum_{j=1}^{n-1}\left(p_j - p_{j-1} - \hat{\mu}\right)^2\right]^2} \qquad (12).$$

Additionally, Lo and MacKinlay (1988) conducted a series of Monte Carlo studies, which resulted in the conclusion that the *VR-Test* as suggested by them and conducted here, as long as *q* is relatively small in comparison to the sample size[21], is reliable and more powerful than plausible alternatives.

Further, as Chow and Denning (1993) point out, n>256 should hold for the *Variance Ratio Test* to have significant power.

III.1.b. Modified R/S-Test

Hurst (1951) first developed the *R/S-Test*[22] in its original form in 1951 for the purpose of hydrological applications. Its objective is to detect long-range dependence in time series data. Nonetheless, while being relatively powerful at this task, Lo (1991) points out that the *classical R/S-Test* will not only detect long-range, but also short-range dependence, while not allowing for the distinction between the two. In other words, its test statistic is upwardly biased towards accepting the long-range dependence null hypothesis when actually it short-range dependence that has been detected. He developed a modification, to improve the test in this sense.

The original R/S statistic ($\tilde{Q}_n$) takes the following form:

$$\tilde{Q}_n \equiv \frac{1}{\sigma_n}\left[\max_{1\le k\le n}\sum_{j=1}^{k}\left(r_j - \bar{r}_n\right) - \min_{1\le k\le n}\sum_{j=1}^{k}\left(r_j - \bar{r}_n\right)\right] \qquad (13),$$

where as

$$\sigma_n \equiv \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(r_j - \overline{r}_n\right)^2} \qquad (14),$$

which is the usual maximum likelihood standard deviation (σ^2) estimator.

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[21] This is due to the skewed empirical distribution of the *Variance Ratio Test*.

[22] The R/S stands for range over standard deviation. More usually it is called rescaled range statistic, though.

The first part in the brackets of equation 13 is the maximum (over k) of the accumulated sums of the first deviations from the sample mean and will always be non-negative.

Similarly, the second part in brackets in (13) is the minimum (over k) of the accumulated sums of the first deviations from the sample mean and will always be non-positive. For obvious reasons the whole bracket in equation 13 is called the range.[23]

For his modification Lo (1991) altered equation 14 and introduced $\hat{\sigma}_n(q)$, which is derived as follows:

$$\hat{\sigma}_n(q) \equiv \sqrt{\hat{\sigma}_x^{\,2} + 2\sum_{j=1}^{q} \omega_j(q)\hat{\gamma}_j} \tag{15}$$

where

$$\hat{\sigma}_x^{\,2} \equiv \frac{1}{n}\sum_{j=1}^{n}\left(r_j - \overline{r_n}\right)^2;\ \omega_j(q) \equiv 1 - \frac{j}{q+1};\ \hat{\gamma}_j \equiv \frac{\left[\sum_{i=2}^{n}\left(r_i - \overline{r_n}\right)\left(r_{i-1} - \overline{r_n}\right)\right]}{n};\ q < n.$$ [24]

Both the autocovariance estimator ($\hat{\gamma}_j$) and the weight adjustment $\omega_j(q)$ in the new denominator of the *R/S-Test* will allow for the cancellation of short-range dependence.[25] In other words, the new modified version will only detect long-range dependence.

Equation 16 shows the final version of the *R/S-Test*:

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[23] The intuition behind this test may become clearer when seen in its original context. Hurst developed the test for river reservoir design. If one was to imagine the following: A river at all time is supposed to have an annual flow of 75. An appropriate reservoir is needed to allow for fluctuations. If the annual flow in years 1 through 6 is 100, 50, 100, 50, 100 and 50 the reservoir will have to hold 25, 0, 25, 0, 25 and 0 in the respective years, as a year with a water flow of 100 has to provide for the years with just 50. In other words, the size of the reservoir has to be 25. To make the connection to the *R/S-Test*, the size of the reservoir is nothing but the range, or the bracket in equation 13. Now if the annual water flow was 100, 100, 100, 50, 50 and 50 the range would need to be 75 in order for a constant flow of 75 to hold. Clearly, the more persistent the water flow is, the larger the reservoir needs to be, as the water surplus, or the lack of water over time accumulates. Hence, the range is the difference of the maximum and the minimum of the accumulated deviations from the mean.

[24] $\hat{\sigma}_r^{\,2}$ and $\hat{\gamma}_j$ are also known as the usual sample variance and autocovariance estimators, respectively.

[25] For a more detailed derivation of the *modified R/S-Test* the reader should refer to Lo (1991), which explicitly describes the advantages of the modification and uses several Monte Carlo simulations for justification.

$$Q_n \equiv \frac{1}{\hat{\sigma}_n}\left[\max_{1\le k\le n} \sum_{j=1}^{k}\left(r_j - \bar{r}_n\right) - \min_{1\le k\le n} \sum_{j=1}^{k}\left(r_j - \bar{r}_n\right)\right] \quad (16)$$

The final step in both the *classic* as well as the *modified R/S-Test* is the calculation of the *Test*-statistic ($\tilde{V}_n(q)$ *or* $V_n(q)$, for the classic and modified version, respectively), which will then be used in comparison with the critical values, in order to test the Null hypothesis (H_0) of no long-range dependence, although allowing for short-term correlation. The statistic is obtained as follows:

$$\tilde{V}_n(q) \text{ or } V_n(q) \equiv \frac{\tilde{Q}_n \text{ or } Q_n}{\sqrt{n}} \quad (17).$$

If the values fall in the range of [0.809; 1.862] H_0 will be accepted and hence one is able to observe a random walk.[26]

III.1.c. General Information on the two techniques

In this study for both, the *VR-Test*, as well as the *R/S-Tests*, the chosen investment horizons (lag lengths (q)) are based on practitioner's behavior. The subsequent qs are one, three, six months and one, two, three, four, five, eight and ten years. They represent the different investment mentalities whether they are short-term and speculative or long-term, conservative in nature. Due to obvious reasons, though, in the case of the *Variance Ratio Test*, the one-month return is not calculated.

Additionally, in the case of the *SmallCap* index, due to its relatively short time range, as the reader will see in the next section, and the requirement of the *VR-Test* for q to be relatively small in comparison to n, the greatest q for which the *SmallCap-VR-Test* is calculated is 60, which is equivalent to an investment horizon of 5 years. [27]

III.2. The Data

The data selection process was mainly driven by two factors. Firstly, monthly returns were preferred, as they represent the highest sensible frequency. Daily or higher frequencies would carry too many short-range disturbances. Secondly, due to the

[26] Critical values are given for a 5% significance level as shown in Lo (1991). Further, the fact that the *modified R/S-Test* eliminates short-range dependence but shows long-range dependence, results in much lower test statistics than in the case of the classical version. One could actually say that the original *R/S-Test* has a certain bias towards assuming long-range dependence.

[27] Based on results by Lo and MacKinlay (1988) and Pan, Chan and Fok (1997) Coggin (1998) suggests $q < 0.5n$, which in case of the here used *SmallCap* data means $q < 0.5(136) \Leftrightarrow q < 68$. Rounding this result to a full year leads to $q \le 60$.

findings of Chow and Denning (1993) the *VR-Test* needs an observation size of at least 256, which implies a start date of December 1982 for the data sets, if the most current observation is March 2004.[28]

The following four different indices, as retrieved from MSCI, were finally found and manipulated for the above tests. They proved the best alternative, but clearly, due to the short time range the comparability to earlier results such as Fama and French (1988) will be limited.

III.2.a.* MSCI-Europe*: (31.12.1969-31.03.2004); price index:

The *MSCI-Europe* index contains stocks of the 15 European Union members as well as Switzerland. Its components are located in the *LargeCap* segment and are both *Value* and *Growth* stocks.[29] This index can be seen as a benchmark, allowing a broad view of the European equity market, which then can be compared with the more specific styles. In the following this index will be labeled "standard" index.

III.2.b.* MSCI-Value/Growth*: (31.12.1974-31.03.2004); price index:

The two *Value* and *Growth* indices are based on the *MSCI-Europe* index in their composition. Prior to 30.05.2003 the distinction between *Value* and *Growth* was made through a price to book value ratio (P/BV); low P/BV corresponded to *Value* whereas a high P/BV marked *Growth*. All securities in the *MSCI-Europe*-index were evenly split into *Value* and *Growth*. After 30.05.2003 not only P/BV, but further attributes are being used to make the distinction between *Value* and *Growth*. The procedure is much more complex and the reader should refer to the MSCI-website (www.msci.com) for a more detailed explanation as this would be beyond the scope of this paper.

III.2.c.* MSCI-SmallCap*: (31.12.1992-31.03.2004)[30]; price index:

The *MSCI-SmallCap* index Europe represents about 40% of the most liquid *SmallCap* securities in the above-mentioned 16 European markets. According to

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[28] Especially in the case of the *SmallCap* index this proved to be highly difficult as the European Financial Markets have only since the early 80's began to grow considerably.

[29] The exact definition according to MSCI is as follows: *"The **MSCI Europe Index**℠ is a free float-adjusted market capitalization index that is designed to measure developed market equity performance in Europe. As of December 2003, the **MSCI Europe Index** consisted of the following 16 developed market country indices: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom."* The reader should refer to www.msci.com for the source of this quote.

[30] The given time range represents the maximum available in US-Dollar denomination. As for a local currency denomination, the time range is 31.12.1996-31.03.2004.

their classification MSCI *SmallCap* securities fall in the range of $200m to $1,500m market capitalization. Unfortunately, as the reader can see, the index does not reach back far enough to fulfill the conditions of the *VR-Test*, which according to Chow and Denning (1993) requires a sample size of $n \geq 256$. The respective sample sizes for the Dollar denominated as well as the local currency denominated *SmallCap* index are $n = 136$ and $n = 88$. This currently represents the best alternative, as no European *SmallCap* index seems to exist, that reaches back far enough in order to fulfill the above requirement. Nonetheless, the author feels that some indication is better than no information at all. Also the *R/S-Test* has no requirement for the sample size, so that the statistics should be useful for conclusions about the behavior of securities in the *SmallCap* range.

III.2.d MSCI-Value-Growth: (31.12.1974-31.03.2004); price index:

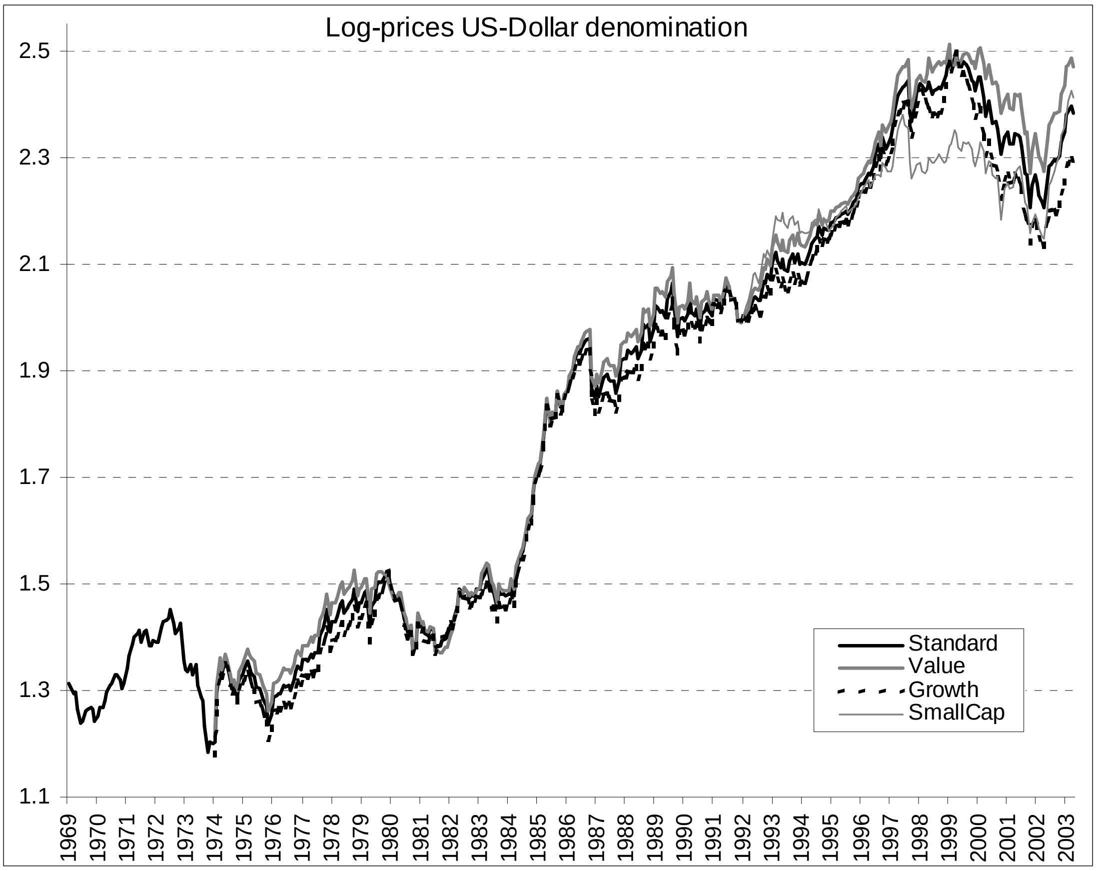
Additionally, a *Value-Growth* differential index was constructed based on the MSCI-*Value* and the MSCI-*Growth* indices. They mimic an investor's decision to buy one equity style and simultaneously selling the other one, which represents a possible investment strategy in equity styles and allows a direct comparison of the two styles. In other words, such an investment strategy is a form of arbitrage between the two styles. A positive reading of the index implies that the style, which is bought is currently producing higher returns, whereas a negative reading of the index represents the opposite. If the two styles are equally profitable the index will surely on average have a zero reading. Common combinations of such differential indexes, or arbitrage indexes as they are also called for obvious reasons, are *Value-Growth* or *LargeCap-SmallCap*, which represent the most extreme ends of the spectrum. The here used *Value-Growth* differential index 'buys' *Value* and 'sells' *Growth*.

III.2.e. Further general information about the data

Firstly, it should be noted that all MSCI indexes were tested in both a US-Dollar as well as a local currency denominated version. Both denominations have their own virtues, but also their very own downsides, hence using both versions seems to be the appropriate solution. If the results are uniform, the broadest coverage will have been achieved. MSCI also offers the indexes in a euro denomination. Unfortunately, these indexes don't reach back far enough. One additional fact about all indices should be pointed out, though. The earliest data observed by any of the above indexes is 31.12.1969, which makes comparisons to earlier studies of this topic, with a much longer time horizon, (e.g. Fama and French 1988) problematic. As said before, it seems that the stock markets experienced times in which the tendency towards mean reversion is greater than in others. This could obviously mean that the chosen time scale mainly represents exactly one such time range, making the comparison to greater time horizons difficult.

Figure 1 shows the log prices of the four main indices denominated in US-Dollar and standardized to 31.12.1992, which is the starting point of the *SmallCap* index.

Figure 1



One can clearly see that in general the *MSCI-Europe* index, the *Value* and the *Growth* indices perform similar, which is not altogether surprising: between them they incorporate exactly the same shares. But it seems to be the *SmallCap* segment that occasionally behaves different. Whereas up to early 1998 its performance is relatively similar to the other indices, it underperforms from then onwards. Only after the general market found its bottom in spring of 2003, did the *SmallCap* index return to a rather market normal development. [31]

[31] This is especially interesting as it is the general believe and the results of many research papers that the *SmallCap* segment, especially in the US, tends to deliver greater overall non-risk adjusted returns (Keim, 1983 or Fama and French, 1993).

IV. Results

The following Section will show and discuss the results for the *Variance Ratio Test* as well as the *R/S-Test* for the above stated investment horizons.

IV.1. *Variance Ratio Test*

Table 1 represents the results of the *Variance Ratio Test* for all 4 indices and the '*Value-Growth*' differential index with the stated lag lengths. The upper half represents the dollar denominated indexes whereas in the lower half the indexes are denominated in local currencies. All grey shaded areas show results, which do not reject the random walk null hypothesis; the according variance ratios are not significantly different from one.

Table 1

Variance Ratio Test ($) — months

	n	3	6	12	24	36	48	60	96	120
Standard	412	1.0426	1.1019	1.2203	1.3516	1.4030	1.3907	1.2688	0.9170	1.0549
		0.5177	*0.7793*	*1.1230*	*1.2407*	*1.1624*	*0.9848*	*0.6122*	*-0.1530*	*0.0918*
Value	352	0.9406	0.9543	1.0847	1.2506	1.2880	1.2846	1.2024	0.6245	0.4460
		-0.6773	*-0.3276*	*0.4122*	*0.8533*	*0.8040*	*0.6948*	*0.4458*	*-0.6668*	*-0.8911*
Growth	352	0.9869	1.0263	1.2455	1.4461	1.5024	1.4030	1.2033	0.7203	0.6999
		-0.1455	*0.1866*	*1.2016*	*1.5324*	*1.4067*	*0.9818*	*0.4458*	*-0.4940*	*-0.4801*
Value-Growth	352	1.3583	1.6049	1.3709	1.1756	1.0391	0.8849	0.8000	0.6273	0.5619
		3.1150	*3.1928*	*1.3072*	*0.4343*	*0.0808*	*-0.2108*	*-0.3354*	*-0.5314*	*-0.5842*
Small Cap	136	1.2819	1.3658	1.3442	0.9077	0.9311	1.1122	1.4590		
		2.0189	*1.6397*	*1.0212*	*-0.1889*	*-0.1168*	*0.1680*	*0.6276*		

Variance Ratio Test (local currency) — months

	n	3	6	12	24	36	48	60	96	120
Standard	412	1.1478	1.2182	1.3074	1.4351	1.5063	1.4918	1.4762	1.3248	1.3325
		1.5444	*1.4794*	*1.4638*	*1.4956*	*1.4468*	*1.2359*	*1.0830*	*0.6005*	*0.5594*
Value	352	1.0686	1.0985	1.1188	1.2086	1.2073	1.1310	1.1014	0.5997	0.4015
		0.6619	*0.6122*	*0.5241*	*0.6721*	*0.5590*	*0.3118*	*0.2187*	*-0.6989*	*-0.9486*
Growth	352	1.1312	1.1562	1.2933	1.4711	1.5840	1.4186	1.2625	0.7751	0.6950
		1.2364	*0.9834*	*1.3466*	*1.5777*	*1.6126*	*1.0073*	*0.5684*	*-0.3943*	*-0.4862*
Value-Growth	352	1.3606	1.6056	1.3711	1.1642	1.0370	0.8786	0.7809	0.6027	0.5247
		3.1284	*3.1895*	*1.3035*	*0.4047*	*0.0761*	*-0.2214*	*-0.3662*	*-0.5649*	*-0.6322*
Small Cap	88	1.3918	1.5467	1.3961	0.9255	0.9686				
		2.2393	*1.9561*	*0.9750*	*-0.1281*	*-0.0450*				

upper line shows the variance ratios (VRs <1 = negative serial correlation and VR >1 = positive serial correlatoin); the lower line depicts the according test statistic; results shaded in grey indicates results in which the variance ratio is not significantly different from one and hence cannot reject the random walk null hypothesis; Investment horizions were chosen with the following condition: q < n/2, as was suggested by Lo and MacKinlay (1988).

As the reader can see, the results are straightforward. Clearly in almost all cases the random walk null hypothesis cannot be rejected by a clear margin, which matches Coggin's (1998) results; the EMH cannot be falsified on the basis of the *Variance Ratio Test*.

Fortunately, these results hold for both used denominations and thereby the drawn conclusions are strengthened; they obviously do not depend on currency fluctuations but seem to be inherent in the data.

Still parts of Table 1 should be seen with a certain caution. As noted before, the test results for the *SmallCap* indexes violate the preconditions for the *VR-Test*; it needs a sample size (*n*) of at least 256 observations, but in the case of the Dollar denominated index *n* is 136 and in the local currency denomination *n* equals just 88. In other words, the tests for the *SmallCap* index can only be seen as an indication and in conjunction with other results, such as the *R/S-Test*. Nonetheless, it should be pointed out, albeit this short coming, the results for the *SmallCap* indexes are not fundamentally different from the results for the other indexes, which comply with the test requirements. This might indicate, that the *SmallCap* index does not follow a mean reverting path, either.

IV.2. *R/S-Test*

The reader will remember that in order to reject the long-term memory H_0 the *R/S-Test* statistic has to be within the range of [0.809; 1.862]. The results for the modified *R/S-Test* in Table 2for most cases indicate a rejection of the mean reverting H_0. This holds especially in the case of the *Value-Growth* differential as well as the *SmallCap* index where all test statistics fall into the rejection range. The results for the *Value* and the *Growth* indexes are fairly straightforward as well. For *q*s up to 12 or in the dollar denominated versions up to 24, the mean reverting H_0 is clearly rejected. For larger *q*s they either reject H_0 as well or fail to do so by only a very small margin. In fact this margin is so small, that if one was to choose a different level of significance (e.g. 1%) H_0 would once more be rejected. Interestingly enough, the only index showing indications of long-range dependence is the standard index. For all *q*s up to 12 months H_0 is rejected. All *q*s larger than 12 clearly cannot reject it, though. On the other hand, the results for the *classic R/S-Test* are straightforward. Except for $q = 1$ none of the results can reject H_0. In contrast to the modified version this seems to be due to short-range dependence, which the classical test is not able to eliminate and hence treats as indistinguishable from long-range dependence.

Table 2

R/S-Test ($)

		n	1	3	6	12	24	36	48	60	96	120
			months									
Standard	modified	412	1.311	1.375	1.517	1.557	2.009	2.270	2.391	2.353	2.381	2.305
	classic	412	1.333	2.175	2.914	3.819	5.108	6.117	6.682	6.752	7.202	7.146
Value	modified	352	1.083	1.319	1.544	1.515	1.860	1.970	1.996	1.937	1.847	1.900
	classic	352	1.078	2.046	2.936	3.700	4.727	5.306	5.579	5.567	5.571	5.823
Growth	modified	352	1.155	1.347	1.582	1.536	1.828	1.964	1.995	1.970	1.884	1.806
	classic	352	1.174	2.100	3.028	3.766	4.650	5.293	5.564	5.652	5.683	5.566
Value-Growth	modified	352	1.150	1.142	1.191	1.230	1.429	1.605	1.681	1.605	1.450	1.604
	classic	352	1.256	1.866	2.325	3.037	3.623	4.314	4.644	4.586	4.346	4.941
Small Cap	modified	136	1.616	1.614	1.633	1.462	1.554	1.573	1.446	1.209	0.935	0.553
	classic	136	1.759	2.584	3.172	3.519	3.865	4.173	3.989	3.421	2.689	1.574

R/S-Test (local currency)

		n	1	3	6	12	24	36	48	60	96	120
			months									
Standard	modified	412	1.565	1.595	1.715	1.787	2.209	2.361	2.393	2.280	2.088	2.059
	classic	412	1.646	2.554	3.318	4.401	5.613	6.360	6.682	6.532	6.324	6.369
Value	modified	352	1.016	1.153	1.350	1.498	1.918	1.911	1.789	1.563	1.515	1.474
	classic	352	1.053	1.822	2.589	3.671	4.865	5.135	4.992	4.482	4.569	4.510
Growth	modified	352	1.289	1.374	1.596	1.674	1.934	1.882	1.774	1.596	1.486	1.393
	classic	352	1.368	2.175	3.075	4.115	4.912	5.066	4.935	4.571	4.479	4.283
Value-Growth	modified	352	1.154	1.374	1.350	1.552	1.134	1.766	1.788	1.640	1.456	1.140
	classic	352	1.262	2.175	2.589	3.636	2.844	4.740	4.981	4.601	4.315	3.516
Small Cap	modified	88	1.418	1.299	1.243	1.241	1.273	1.121	0.928	0.857		
	classic	88	1.576	2.112	2.422	3.006	3.193	2.976	2.468	2.354		

areas shaded in grey indicate *R/S-Test* results which reject the long-term memory null hypothesis; critical values at 5% level: [0.809;1.862]. Any values outside this range indicate (long-range) dependence

IV.3. Implications

Essentially, the above tests duplicate Coggin's results from 1998 for the US financial markets and hence come as no surprise. In general both, the *VR-Test* as well as the modified *R/S-Test* indicate a random walk and as such market efficiency of the *weak* form in European equity style indexes.

At this point it should be pointed out, though, that a random walk is a necessary condition for the *weak* form EMH, but cannot be seen as a sufficient condition. To put it differently, all *weak* form efficient markets follow a random walk, but not all random walks are necessarily *weak* form efficient. The reason for this is that some information in past price or return data might due to some reason be excluded from usage.[32] This

[32] Possible reasons for information not being used could be non-tradability or high costs. The case of high costs is straightforward, if it is more expensive to obtain the information than its profit prospects are, this information will remain idle and could not be incorporated in a share price. Non-tradability of information would essentially have the same result. A person holding information and not being able to use it him/herself would, due to some trade restrictions for example, not be able to sell the information. He/She would end up being indifferent to making the information public or keeping it. As making it public would involve costs of some kind, it is more likely than not, that the information will not become public. In other words, the information would exist, but could not be incorporated in the price.

would result in a random walk, but essentially it would not be efficient according to the above definition by Fama (1965). Still as such a situation can hardly be identified, the detection of a random walk is as good as the verification of the *weak* form market efficiency. This holds up to the point where the EMH can be falsified.

Finally, it remains unclear whether the above results are purely a temporary phenomenon or whether they apply universally. If the reader refers back to the literature review he/she will remember, that Fama and French (1988) found long-term memory, which was time varying. The greatest evidence for mean reversion was found in the period prior to WWII. This lead Kim *et al.* (1991) to conclude, that mean reversion is purely a pre-WWI phenomenon and is not relevant anymore. But can such a conclusion also be drawn for the European equity style markets? Unfortunately, the available data does not allow for such an investigation; it simply does not reach back far enough. But interestingly, even such a prolonged market anomaly as the internet bubble of the late 90s, which if tested by itself should not be able to yield a random walk, is not able to distort the above result enough, as to reject the *weak* form market efficiency. This leads to the conclusion, that if the above tests were run excluding the late 90s, the results would be even stronger in favor of the *weak* form EMH.

IV.4. Further research areas

As always the above results have to be seen as an indication only, and only additional research in this field can support the drawn conclusions. The following are suggests as to how this additional research could look like.

A similar study with the same time horizon of different financial markets could be undertaken, as to find out whether the results can be duplicated for other regions of the world. A random walk in equity style indexes in other areas, besides the US and Europe, would further support the general notion of market efficiency. If this would not be the case, the question whether the results for the US and Europe or the whether rest of the world behaves like the norm, would arise.

Finally, if at some point in time data with a greater time horizon can be obtained, a sub-section analysis, as Fama and French (1988) performed it, would seem appropriate. This might allow to identify a time period in which a clear non-randomness is located (such as the late 90s for example) or it would verify the above results for all past periods. In the former case, it again would be necessary to find out which state, randomness or mean reversion, represents the exception.

V. Conclusion

After a brief introduction into the underlying concepts of random walk, mean reversion and equity styles, as well as a comprehensive literature review on the topic of random walk testing and a description of the methodology the above discussion arrived at the following major result.

The *VR-Test* as well as the *modified R/S-Test* indicate a random walk across all sections of the European equity style markets.

In conclusion, it has to be said that the above results are essentially duplication of the results by Coggin (1998) which he obtained for the United States. As such they are hence no surprise and provide further indications for the validity of the *weak* form EMH. Still, due to the relatively short data range, it remains unclear whether these results are just time specific or a general phenomenon. To answer this further research is needed of the form suggested above.

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